FOSSIL DICOTYLEDONOUS WOODS FROM YELLOWSTONE NATIONAL PARK

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TWO REGIONS OF YELLOWSTONE NATIONAL PARK contain successive horizons of silicified tree trunks, many in upright position, preserved in volcaniclastic rocks. The spectacular sequence of more than 25 forests at Specimen Ridge and Amethyst Mountain, along the south bank of the Lamar River in the northeastern region of the Park, was discovered by Holmes about a century ago. These fossil forests have been described by several authors including Knowlton (1899) and Dorf (1960, 1964). The lesser known but equally striking succession of fossil forests in the northwestern Gallatin area has been described by Andrews (1939) and Andrews and Lenz (1946). The fossil forests in the two areas, more than 40 miles apart, are in beds of approximately equivalent ages.

More than 100 species of fossil plants, 75 percent of them dicotyledonous, have been identified (Dorf, 1960, 1964) from beds along the Lamar River, chiefly from leaves in finer sediments of the formation containing the fossil forests. This leaf flora has predominantly warm-temperate and subtropical affinities but includes some forms with modern relatives in the tropics. Although the broad climatic implications of this Yellowstone flora are clear, MacGinitie (1974) has pointed out that Knowlton (1899) designated many of the fossil plants by names that are stratigraphic rather than botanical, and that, despite some updating by Dorf (1960), the Yellowstone flora is in need of revision. Consequently, the systematic affinities of many Yellowstone dicotyledonous plants remain in doubt.

Warmer climatic conditions than were probable for the Yellowstone fossil flora are suggested by the Kisinger Lakes flora (MacGinitie, 1974) from beds of similar age some 80 miles to the southeast in the Wind River Basin, Wyoming. This flora apparently lacks close botanical similarity to the Yellowstone fossil flora.

Despite the dominance of angiospermous taxa in the Yellowstone leaf flora, coniferous wood is more abundant than hardwoods in the fossil forests. Both types of wood have been described by Felix (1896), Knowlton (1899), Platen (1908, 1909), and Beyer (1954); Conard (1930), Read (1930), and Andrews (1939) described only conifers. Like the leaf flora, the Yellowstone dicotyledonous woods need re-examination. Only three of them have been studied in the last half-century (Beyer, 1954).

To investigate the identity of the angiospermous plants in the Yellowstone fossil forests, one of us (Scott) has made collections of dicotyledonous woods from Specimen Ridge and Amethyst Mountain along the Lamar River, and in the Gallatin area. To avoid harm to the remains of trees in place, only detached pieces were obtained from the slopes; conse-

quently, the collections represent a generalized composite, both vertically and horizontally, of the trees from the many forest levels. The localities are designated as follows:

U.S.G.S. Paleobot. Loc. No. D2054A. Amethyst Mountain, Yellowstone National Park, Wyoming. Wood collected in Lamar River Formation from north and east facing slopes about 3 miles southwest of the intersection of Soda Butte Creek and the Lamar River about 400 to 1400 feet above river level. See Tower Junction (GQ-1247) Quadrangle, Wyoming-Montana, and Abiathar Peak (GQ-1244) Quadrangle, Wyoming, 1975.

U.S.G.S. Paleobot. Loc. No. D2054B. Specimen Ridge, Yellowstone National Park, Wyoming. Wood collected along north facing slopes in Lamar River Formation about 2 miles south and about 1000 to 1400 feet above the Lamar River from about 4 to 7 miles east of Tower Junction. See Tower Junction (GQ-1247) Quadrangle, Wyoming-Montana, 1975.

U.S.G.S. Paleobot. Loc. No. D2089. Gallatin Fossil Forest, Yellowstone National Park, Montana. Wood collected between 8000 and 9200 feet elevation on the south flanks and spurs of Big Horn Peak, at the head and on the ridges 1 to 3 miles upstream (to the northeast) along an unnamed tributary that joins Specimen Creek about 2 miles northeast of the mouth of Specimen Creek at the Gallatin River. See Crown Butte, Montana, 15′ Quadrangle, U.S.G.S. 1955.

More than 30 types of dicotyledonous woods have been recognized in our collections from the Lamar River and Gallatin fossil forests. These will be described in a series of papers: systematic descriptions will be included in the first papers, while most ecological and floristic discussion will be reserved for the final one.

GEOLOGIC OCCURRENCE AND AGE

The Lamar River and Gallatin fossil forests occur in strata of the Absaroka Volcanic Supergroup in the Absaroka volcanic field, developed during Eocene time over some 9000 square miles in northwest Wyoming and southwest Montana. This large field, studied recently by Smedes and Prostka (1972), consists of a number of stratovolcanoes and the air and water-deposited materials derived from them. The rocks in the vent areas consist of a chaotic assemblage of lava flows, autoclastic flow breccias, avalanche debris, mudflows, and tuffs. Alluvial facies consisting of well-bedded, reworked volcanic sediments grade outward from and interfinger with rocks of the vent facies, forming the rock units included in the Absaroka Volcanic Supergroup. The Gallatin fossil forest occurs in one such unit, the Fortress Mountain Member of the Sepulcher Formation. This formation grades laterally southeastward into the Lamar River Formation, the basal volcaniclastic unit throughout much of the northeastern portion of the Park. The Lamar River Formation contains both the Specimen Ridge and Amethyst Mountain fossil forests.

At the Amethyst Mountain fossil forest, the north- and east-facing

beds of the Lamar River Formation are overlain unconformably by the Eocene Langford Formation, which extends from elevations of about 8500 feet to cap Amethyst Mountain. The Langford Formation, lighter in color than the Lamar River Formation, contains very little fossil wood in this area (H. J. Prostka, pers. comm., March 30, 1976).

Events leading to the preservation of vertical sequences of forests in both the Sepulcher and Lamar River Formations appear to be similar. Volcanic materials now a part of these formations overwhelmed, buried, and contributed to the rapid silicification of the forests growing on the series of transitory soil surfaces which developed as the formations accumulated.

A potassium-argon age determination from the lower part of the Sepulcher Formation gave an age of 49.2 ± 1.5 m.y. (J. D. Obradovitch, in Smedes & Prostka, 1972). A similar late early to early middle Eocene age is indicated for the Lamar River Formation, which grades laterally into the Sepulcher Formation. This radiometric age determination is consistent with the age inferred for the Lamar River fossil leaf flora by Dorf (1960).

SYSTEMATIC DESCRIPTIONS

Many named species of fossil woods are placed by custom in genera whose names include a categorical suffix, now usually "-oxylon." For Tertiary woods having affinities with modern plants, such generic names are formed by adding this suffix to the name of the modern taxon, usually the genus, to which the fossil form appears to be most closely related. Such "-oxylon" genera are not required by the International Code of Botanical Nomenclature, whose preamble states that "The purpose of giving a name to a taxonomic group is not to indicate its characters or history, but to supply a means of referring to it and to indicate its taxonomic rank." (Stafleu *et al.*, 1972). Some examples of misleading names that have arisen through error or loose circumscription in the application of this convention are given by Lakhampal and Dayal (1968).

Despite some shortcomings, the apparent neatness of this approach to fossil wood nomenclature has led some students of Tertiary dicotyledonous woods (e.g. Kramer, 1974a) to feel that all named species of fossil woods should be assigned to organ and form genera whose names include the "-oxylon" suffix. Müller-Stoll and Mädel (1967) even consider that it is improper to assign an extinct species based on fossil wood to an extant genus. We find this approach extreme; it is certainly inconsistent with the practice of most paleobotanists when naming the majority of such detached plant parts as leaves, fruits, and seeds of Tertiary age.

In examples in which the fossil wood species falls clearly within the structural limits of a single modern genus, relative age rather than details of anatomy inevitably becomes the operative factor in delimiting the equivalent "-oxylon" genus. Schopf (1969) points out that a truly disjunct range in time is an impossibility for any group that has phyletic

unity. Because phyletic unity, as demonstrated by common morphology, is the reason for the choice of the modern base name for the "-oxylon" genus, age difference alone seems at best a dubious criterion for the establishment of that "-oxylon" genus. In such cases, encumbering existing nomenclature for the sake of uniformity in applying an informal convention seems to us only to obscure the contribution made by the fossil material to the geologic history of the genus. Consequently, in this series of papers, those fossil wood species whose anatomical features we regard as consistent with those of a single modern genus will be assigned to that genus.

BETULACEAE

Alnus latissima Wheeler, Scott, & Barghoorn, sp. nov. FIGURES 1–3.

Growth rings. Present, distinct, 7–10 mm. wide.

Vessel elements. Diffuse porous, little or no change in vessel diameter and density throughout growth ring; tangential diameter 38–85 μm., mean 55 μm.; solitary and in radial multiples of 2–4 (rarely 5), a few clusters; density 70–136 per square mm.; perforation plates exclusively scalariform with 13–26 bars; intervascular pitting opposite and alternate, 5–6 μm. across; length 440–1045 μm.

Rays. Uniseriate and aggregate; homocellular; uniseriate rays 4–34 (48) cells; 92–760 μm. (1045 μm.) high.

MATERIAL. One specimen of silicified, mature secondary xylem, 45 $\times$ 55 $\times$ 48 mm.

HOLOTYPE. U.S.G.S. Fossil Wood Collection No. D2089–13. The species is named with reference to the unusually wide growth rings.

LOCALITY. Gallatin Fossil Forest: U.S.G.S. Paleobot. Loc. No. D2089.

A number of salient features of the fossil indicate that it is a species of *Alnus*: small vessels solitary and in radial multiples, aggregate and uniseriate homocellular rays, scalariform perforation plates, and both alternate and opposite intervascular pitting. The somewhat similar woods of *Alnus* and *Betula* are separable on the basis of various characters. Both opposite and alternate intervascular pitting occur in *Alnus*; only alternate pitting occurs in the mature wood of *Betula*. Exclusively uniseriate rays occur in *Alnus*; multiseriate rays occur in *Betula* (Hall, 1952). Within *Alnus*, the fossil species with its aggregate rays does not belong to the section ALNOBETULA in which such rays are lacking, but it is not possible to determine with which of the other two sections it may have affinities. Only one species of the section CREMASTOGYNE and none of the section CLETHROPSIS were available for study (Hall, 1952).

The Yellowstone wood has wider growth rings (7–10 mm.) than have been reported for extant species of *Alnus*, but it is otherwise indistinguishable from extant members of the genus. One specimen of *Alnus acuminata*

(Hw 19514) from Argentina differs from species of *Alnus* from more northerly regions, as it lacks distinct growth rings and has thinner-walled, larger imperforate elements and a lower vessel density.

In North America pollen and foliage of *Alnus* are known from Late Cretaceous and younger rocks (Wolfe, 1973). Pollen of *Alnus* is reported from the Kisinger Lakes flora (Leopold, in MacGinitie, 1974) and from the fossil forest beds in Yellowstone National Park (Fisk & DeBord, 1974). However, to the best of our knowledge this is the first fossil wood of *Alnus* described from the Tertiary of North America. There are two reports of *Alnus* wood from the Pliocene of Austria and Germany (Müller-Stoll & Mädel, 1959) and one from the Tertiary of Rumania (Petrescu & Nuta, 1969). *Alnus* occurs on all continents of the Northern Hemisphere; it extends southward in Asia to Assam and in the New World through Mexico and Central America. In the Andes the genus ranges to Peru, Bolivia, and northern Argentina (Willis, 1973).

Carpinus saximontana Wheeler, Scott, & Barghoorn, sp. nov.
FIGURES 4, 5.

Growth rings. Distinct; wavy in outline; 5–16 mm. broad.

Vessel elements. Solitary, in radial multiples of 2–14, or rarely in pore clusters; tangential diameter in early wood 32–87 μm., tangential diameter in late wood 23–60 μm.; gradually decreasing in diameter through the growth ring, longest radial multiples in late wood; length 550–780 μm.; perforations simple; intervascular pitting alternate, medium, angular due to crowding; pits to ray parenchyma oval; slightly bordered; tyloses thin-walled, infrequent.

Parenchyma. Difficult to see in cross section; in longitudinal section strands of 10 or more cells observed; apparently apotracheal diffuse; cells slightly inflated, occasionally crystalliferous.

Rays. 1 and 2 cells wide and aggregate, aggregate rays widely spaced; homocellullar; biseriate rays 10–48 cells, 110–920 μm. high; uniseriates 3–17 cells, 55–276 μm. high.

Imperforate tracheary elements. Thin-walled; length and pitting not observed.

MATERIAL. Three specimens of silicified, mature secondary xylem, the type specimen measuring 90 × 48 × 65 mm.

HOLOTYPE. U.S.G.S. Fossil Wood Collection No. D2089–16. The species name refers to the Rocky Mountains, where this taxon constitutes the first Eocene record.

LOCALITY. Gallatin Fossil Forest: U.S.G.S. Paleobot. Loc. No. D2089.

The combination of features present in this fossil wood (aggregate rays accompanied by uniseriate and biseriate rays, alternate intervascular pitting, and small vessels occurring in radial multiples) is characteristic of

the Betulaceae. *Carpinus* is the only genus in the family that contains species with both aggregate rays and predominantly simple perforation plates; thus, the fossil is assigned to this genus. *Carpinus* includes two sections, CARPINUS, with predominantly or exclusively simple perforation plates, and DISTEGOCARPINUS, with exclusively scalariform perforation plates. The simple perforation plates of this fossil *Carpinus* wood ally it with the section CARPINUS.

Hall (1952) describes the vessel arrangement in *Carpinus* as diffuse porous, and his figured specimens show relatively uniform vessel size and distribution within a growth ring. According to Hall, growth rings in *Carpinus* range in width from 125 μm. to 4 mm. In the Yellowstone fossil *Carpinus,* there is a more conspicuous change of vessel size and distribution within a growth ring, and the growth rings are 5 to 16 mm. wide. However, a specimen of modern *C. caroliniana* Walter (Hw 9857) with wide growth rings (5–7 mm.) showed changes in vessel diameter and distribution comparable to those in the fossil *C. saximontana.* Slides of six specimens of *C. caroliniana* Walter were examined; differences among these specimens are as great as the differences among some of the other ten species of the genus examined.

Carpinoxylon ostryopsoides Page (1970) from the Upper Cretaceous of California is the only other North American fossil wood that can be assigned with confidence to the tribe Coryleae. This wood has "flamelike" vessel distribution, a feature of *Ostryopsis* and *Corylus. Carpinoxylon pfefferi* Platen (1908) was described from the Auriferous Gravels of California, but Müller-Stoll and Mädel (1959) believe that the specimen is not betulaceous as the rays are heterocellular and up to 14 cells wide.

Wood of *Carpinus* is not common in the fossil record. In their comprehensive review of fossil woods of the Betulaceae, Müller-Stoll and Mädel (1959) list only four species: two from Europe, one from the Sahara, and one from Japan. The ages of only two of these species are known with certainty: both are Miocene. All four species belong to the section CARPINUS, and were assigned to an organ genus, *Eucarpinoxylon,* by Müller-Stoll and Mädel.

Prakash *et al.* (1971) described two betulaceous woods from the Oligocene of Bohemia as species of the organ genus *Coryloxylon.* One species had features common to *Corylus* and *Ostryopsis,* the other features common to *Corylus* and section DISTEGOCARPINUS of *Carpinus.*

Fisk and DeBord (1974) report pollen of *Carpinus* from the strata containing the fossil forests in Yellowstone National Park, but there is no other record of the genus in the Eocene of the Rocky Mountains (Leopold & MacGinitie, 1972; MacGinitie, 1974). *Carpinus saximontana* represents the earliest known occurrence of wood with the structural features of the section CARPINUS and the first record of fossil wood of *Carpinus* in North America.

According to Willis (1973), *Carpinus* has 35 species which are north temperate (chiefly East Asian) in distribution, with only one species, a member of the section CARPINUS, indigenous to North America.

Carpinus absarokensis Wheeler, Scott, & Barghoorn, sp. nov.
FIGURES 6, 7.

Growth rings. Distinct, 3–5 mm. wide.

Vessel elements. Solitary, in radial multiples of 2–5, and less frequently in pore clusters; gradually decreasing in size through growth ring; tangential diameter of early wood vessels 51–97 μm., mean 74 μm.; tangential diameter of late wood vessels 32–60 μm., mean 46 μm.; in some growth rings the last portion of the late wood devoid of pores; length 635–850 μm.; perforations predominantly simple; intervascular pitting alternate to 10 μm. across; angular in outline where crowded; pits to ray parenchyma oval in outline.

Parenchyma. In longitudinal sections strands with up to 10 cells observed, apparently apotracheal diffuse distribution.

Rays. 1 to 3 (rarely 4) cells wide and aggregate; homocellular and occasionally heterocellular; multiseriate rays 5–39 cells, 94–740 μm. high; uniseriates 2–16 cells, 47–357 μm. high.

MATERIAL. One specimen of silicified, mature secondary xylem, 38 × 65 × 125 mm.

HOLOTYPE. U.S.G.S. Fossil Wood Collection No. D2054B-32. The species name indicates its occurrence in the Absaroka Volcanics.

LOCALITY. Specimen Ridge Fossil Forest: U.S.G.S. Paleobot. Loc. No. D2054B.

This species of *Carpinus* differs from *C. saximontana* in two features. Radial multiples are composed of no more than 5 vessels in *Carpinus absarokensis*, while in *C. saximontana* there are up to 14 pores per multiple. Some axial parenchyma cells in the Gallatin specimens are inflated and crystalliferous; no such cells were seen in *Carpinus absarokensis* from Specimen Ridge. These two species differ from one another in as many characters as do any other fossil wood species of *Carpinus* (see Müller-Stoll & Mädel (1959) for descriptions of the other species).

There is the possibility that the Gallatin woods and the wood from Specimen Ridge may represent but one species. Six specimens of *Carpinus caroliniana* Walter were examined. It was observed that the wider the growth ring, the more vessels the radial multiples at the end of the growth ring contained. The growth rings of the Specimen Ridge *Carpinus* are not as wide as those in the Gallatin woods. Five of the specimens of *C. caroliniana* Walter had inflated crystalliferous ray cells; one lacked such cells. Presence of crystalliferous cells varies within this one extant species. *Carpinus caroliniana* has a wide range and occurs in the eastern United States, Mexico, Guatemala, and Honduras. All but one of the specimens examined was from the eastern United States. The Mexican specimen was distinct in possessing abundant one-cell-wide bands of parenchyma. Variation in number of vessels per radial multiple and ray width were observed

in four other species in which more than one specimen was studied.

Although the differences between the Gallatin and Specimen Ridge woods assigned to *Carpinus* may be interspecific, they are named as separate species. There is interspecific variation in *Carpinus*, as evidenced by *C. caroliniana*, but wood of different species of *Carpinus* is in some cases more similar than *C. saximontana* and *C. absarokensis*. All three of the Gallatin specimens differ in the same features from the Specimen Ridge woods. For these reasons, the woods from the two localities are given different names.

LAURACEAE

Ulminium porosum Wheeler, Scott, & Barghoorn, sp. nov.

FIGURES 8–11.

Growth rings. Present, indistinct without magnification.

Vessel elements. Diffuse porous, solitary and oval, or in radial multiples of 2–5, mostly 2–3; tending to a diagonal arrangement; tangential diameter 40–115 μm., mean 92 μm.; radial diameter of solitary pores 75–185 μm., mean 120 μm.; 32–85 per square mm.; length 230–505 μm.; perforation plates simple; intervascular pitting alternate; medium-sized, angular in outline due to crowding; pitting to ray parenchyma variable, rounded, oval, or irregular, occasionally unilaterally compound, simple to slightly bordered; tyloses present.

Parenchyma. Difficult to distinguish in cross section; in tangential section strands observed in association with vessel elements.

Rays. Multiseriates to 5 cells wide, 8–56 cells, 140–1400 μm. high, with uniseriate margins of 1–3 rows of square and occasionally upright cells; uniseriates rare, to 7 cells high; inflated cells occasionally occurring in the marginal rows of the multiseriate rays.

Imperforate tracheary elements. Thin-walled, pitting not observed.

MATERIAL. Four specimens of mature, silicified, secondary xylem.

HOLOTYPE. U.S.G.S. Fossil Wood Collection No. D2054A-24, 40 × 50 × 73 mm. The specific name refers to the high vessel density.

LOCALITIES. Gallatin Fossil Forest: U.S.G.S. Paleobot. Loc. No. D2089. Amethyst Mountain: U.S.G.S. Paleobot. Loc. No. D2054A. (The holotype specimen is from Loc. No. D2054A.)

Four specimens have been placed in this taxon, two from the Gallatin fossil forest and two from Amethyst Mountain. They differ slightly in the density and tangential diameter of the vessels. According to Stern (1954) and Süss (1958), the presence of the following combination of features delimits the Lauraceae from other dicotyledonous families: a) diffuse porous wood; b) vessels predominantly solitary with a tendency

for the formation of short, radial multiples; c) crowded alternate intervascular pitting; d) heterocellular rays, mostly 1 to 3 cells wide; e) paratracheal vasicentric parenchyma; and f) presence of idioblasts. These Yellowstone specimens have a higher vessel density than is typical for the family (Metcalfe & Chalk, 1950; Stern, 1954), but because they have the distinctive combination of features listed above they are placed in the Lauraceae.

Unfortunately, *Ulminium* is the valid generic name for woods of the Lauraceae. Unger (1842) first used the name *Ulminium diluviale* for a fragment of wood which Felix (1883) re-examined and found to have abundant secretory cells and other characteristics of the Lauraceae. Page (1967) and Romero (1970) have discussed the validity of *Ulminium* for lauraceous fossil woods. In the past most fossil woods thought to belong to the Lauraceae have been assigned to *Laurinoxylon* Felix.

More recently, Page (1967) described *Ulminium pattersonensis* and *U. mulleri* from the Upper Cretaceous of California. These two species may represent the stem and root of the same lauraceous plant (Page, 1967). The pore multiples are 8-shaped rather than θ-shaped; the vessels are thick-walled and not arranged in diagonals.

Prakash, Brezinova, and Buzek (1971) and Prakash, Brezinova, and Awasthi (1974) have described two new Bohemian species of *Ulminium* (*Laurinoxylon*) and have listed the several European occurrences reported since Süss's (1958) monograph of fossil lauraceous woods.

It is impossible to correlate the species of *Ulminium* (*Laurinoxylon*) with modern species or even genera within the Lauraceae. We compared the wood of eight different specimens of *Cinnamomum camphorum* and found vessel diameter and density, parenchyma abundance, and frequency of oil cells to vary as much among these individuals as between different species of the same genus. Difficulties in distinguishing genera on the basis of wood anatomy have been discussed by Stern (1954) and others.

Leaves of *Cinnamomum*, *Cryptocarya, Litsea, Persea,* and *Sassafras* are reported from the late early Eocene of Wyoming (MacGinitie, 1969), and there are two species of *Laurophyllum* in the Kisinger Lakes flora (MacGinitie, 1974). The 32 genera of Lauraceae are primarily tropical and subtropical, with the chief centers of distribution for the family being in Southeast Asia and Brazil.

Laurinoxylon pulchrum Knowlton (Knowlton, 1899; Platen, 1908) and *Perseoxylon aromaticum* Felix (Felix, 1896; Knowlton, 1899) are two taxa of fossil woods from the Specimen Ridge area of Yellowstone Park which were assumed at the time they were described to belong in the Lauraceae. We have examined the type of *Laurinoxylon pulchrum* Knowlton and have found it to belong to the Leguminosae, rather than the Lauraceae. This wood will be discussed in detail in a subsequent paper. Süss (1958) suggested that *Laurinoxylon pulchrum* does not belong to the Lauraceae because there are no oil cells, and the vessel to parenchyma pitting was not described or illustrated by Knowlton. Platen (1908) described another specimen of this species; this specimen, from Amethyst Mountain,

is semi-ring porous and has small vessel to parenchyma pitting. *Sassafras* is the only lauraceous wood that is semi-ring porous, and small vessel to parenchyma pitting is not characteristic of the family. *Perseoxylon aromaticum* has larger vessels, a lower vessel density, no oil cells, and more parenchyma than *Ulminium porosum*. It is not possible to determine from the description and illustrations whether *P. aromaticum* was correctly assigned to the Lauraceae.

There are three types of fossil lauraceous woods from North America listed in Süss's (1958) monograph on fossil woods of the family. *Laurinoxylon bakeri* Berry from Texas has relatively abundant diffuse apotracheal parenchyma, as well as paratracheal parenchyma, low rays from 2 to 18 cells high, and some septate fibers. The diagnoses of *L. californicum* (Platen) Süss and *L. eberi* (Platen) Süss are unaccompanied by illustrations (Platen, 1908), and the descriptions are in such general terms that adequate comparison of these woods is impossible.

Ulminium parenchymatosum Wheeler, Scott, & Barghoorn, sp. nov.
FIGURES 12–14.

Growth rings. Indistinct.

Vessel elements. Tangential diameter 54–138 μm., mean 92 μm.; predominantly solitary (71%), in radial pairs (26%), and rarely in radial multiples of 3 (3%); multiples 8-shaped, rather than θ-shaped; walls 9.5–11 μm. thick; 5–8 per square mm.; length 285–430 μm.; perforations apparently all simple; intervascular pitting alternate, generally 8 μm. across; pits to parenchyma variable, not similar to intervascular pitting, often elongated horizontally, up to 14 μm. across; tyloses present.

Parenchyma. Vasicentric, aliform, and aliform-confluent.

Rays. Multiseriates to 4 cells wide; 7–42 (60) cells, 170–1035 μm. (1400 μm.) high; generally with a single marginal row of upright and square cells; occasionally with an inflated marginal cell; uniseriates 1–8 cells, 55–265 μm. high, some composed exclusively of upright and square cells; 4–8 per mm.

Idioblasts. Thin-walled cells, 15–35 per square mm.; as isolated cells or in small groups of 2–4; as single cells scattered among the fibrous elements, or to the side of a ray; 250–460 μm. long, tangential width 29–46 μm.

MATERIAL. One specimen of mature, silicified, secondary xylem 150 × 70 × 130 mm.

HOLOTYPE. U.S.G.S. Fossil Wood Collection No. D2054B-40.

LOCALITY. Specimen Ridge: U.S.G.S. Paleobot. Loc. No. D2054B.

This wood exhibits the combination of features listed previously as diagnostic of Lauraceae. It differs from *Ulminium porosum* and other species of fossil lauraceous wood by the presence of numerous idioblasts

scattered among the fibrous elements and of more abundant parenchyma.

Within the Lauraceae, idioblasts occur most commonly in ray or axial parenchyma cells, and less frequently in the fibrous ground tissue (Stern, 1954, and personal observation). Stern (1954) describes the idioblasts as "roughly barrel-shaped; that is vertically elongated and widest at the middle. These cells are distinguished from other similar cells by their non-lignified thin walls." The Yellowstone fossil described above has idioblasts which occur most frequently among the fibrous elements and only occasionally as marginal ray cells. In cross section, they are distinguished by thin walls and appear similar to idioblasts as figured by Stern (1954, *fig. 6*) and Jane (1970, *fig. 73C*). In tangential section the isolated cells are not as inflated tangentially as is figured by Stern (1954, *fig. 10*) or Jane (1970, *fig. 73B*) and do not appear barrel-shaped as is implied to be typical of these cells. Slides of the wood of 32 genera of Lauraceae (*fide* Kostermans) were examined to determine if idioblasts with a shape and distribution similar to the fossil existed. Cells with a similar shape to those in the fossil were found in some species of *Aiouea*, *Aniba*, *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Licaria*, *Litsea*, *Mezilaurus*, *Nectandra*, *Ocotea*, and *Phoebe*. The idioblasts were most frequently in ray and/or axial parenchyma, and isolated cells were mostly barrel-shaped. Idioblasts not markedly barrel-shaped and exclusively or predominantly in the ground tissue were observed in some species of *Aniba*, *Beilschmiedia*, and *Ocotea*. It is possible that these characters may occur in other genera. The presence or absence, distribution, and abundance of idioblasts may vary greatly within a genus. For example, in *Ocotea* there were species without any idioblasts, species where idioblasts occurred only in ray tissue, and others where idioblasts occurred only isolated among the fibrous elements.

As was discussed in relation to the species of *Ulminium* from Gallatin and Amethyst Mountain, in the Lauraceae there is as much variation within a genus as between genera; it is not possible to distinguish different genera, with the exception of ring-porous species of *Sassafras*. The species of *Ulminium* described above differs from previously diagnosed species of fossil lauraceous wood by the presence of numerous idioblasts among the fibrous elements and the relatively abundant parenchyma.

Ulminium eocenicum Wheeler, Scott, & Barghoorn, sp. nov.

FIGURES 15–17.

Growth rings. Indistinct.

Vessel elements. Tangential diameter 55–115 μm., mean 92 μm.; predominantly solitary (77%), occasionally in radial pairs (18%), and more rarely in radial multiples of 3 and clusters (5%); multiples 8-shaped, rather than θ-shaped; solitary vessels circular in outline, walls generally 10–11 μm. thick; 7–10 per square mm.; length 200–330 μm.; perforations simple; intervascular pitting alternate, small; pits to parenchyma variable, irregular in outline, at times unilaterally compound; occasional tyloses.

Parenchyma. Scanty paratracheal and vasicentric; also 3–8-cell-wide, widely spaced tangential bands.

Rays. Multiseriates to 4 cells wide; 6–30 (48) cells, 180–675 μm. (1105 μm.) high; generally with a single marginal row of square and upright cells, with up to 7 cells in the uniseriate margin; uniseriates 1–7 cells, 55–345 μm. high; 5–9 per mm.

Idioblasts. 1–2 per square mm., as isolated cells among the fibrous elements or adjacent to a ray, 220–295 μm. long, tangential width 23–32 μm.

MATERIAL. One specimen of mature, silicified secondary xylem measuring 100 × 72 × 85 mm.

HOLOTYPE. U.S.G.S. Fossil Wood Collection No. D2054B-38.

LOCALITY. Specimen Ridge: U.S.G.S. Paleobot. Loc. No. D2054B.

This species shares many features with *Ulminium parenchymatosum.* The salient features, which indicate that it is a member of the Lauraceae, are listed in the discussion of *Ulminium porosum. Ulminium eocenicum* is distniguished from *Ulminium parenchymatosum* by the smaller intervascular pitting, and the less abundant parenchyma and idioblasts.

MAGNOLIACEAE

Magnoliaceoxylon, gen. nov.

This is a genus for fossil woods belonging to the family Magnoliaceae but not assignable to an extant genus in the family. Structural features include most or all of the following: small vessels, solitary and in radial multiples, opposite and scalariform intervascular pitting, scalariform or in part simple perforation plates, and heterocellular rays usually not more than four cells wide with few uniseriates.

TYPE SPECIES: *M. wetmorei.*

The genus name *Magnolioxylon* was first used by Hofmann (1952) for a single species of Oligocene wood. No generic diagnosis was given, and her description of the type species, *M. michelioides,* does not include sufficient details to confirm its relationship either to *Michelia* or to the Magnoliaceae. Schönfeld (1958) and van der Burgh (1973) have indicated that the species does not correspond to *Michelia.* Since Kramer (1974b) mentions details not provided by Hofmann, he has apparently examined the type material. He records a combination of characters for *Magnolioxylon michelioides* that does not occur in the Magnoliaceae and concludes that the genus *Magnolioxylon* must be excluded from the family.

This nomenclatural situation, unfortunate but not unique, leaves no existing generic category for fossil magnoliaceous woods not assignable to extant genera. *Magnoliaceoxylon* is erected for such fossil woods.

Magnoliaceoxylon wetmorei Wheeler, Scott, & Barghoorn, gen. et sp. nov. FIGURES 18–20.

Growth rings. Present, indistinct.

Vessel elements. Predominantly solitary, or in radial multiples of 2–3; diffuse porous; tangential diameter 35–125 μm., mean 75 μm.; radial diameter solitary pores 55–135 μm.; 380–959 μm. long; perforation plates scalariform with 8–26 bars, most commonly less than 15 bars, bars occasionally forked; intervascular pitting opposite to scalariform; pit-pairs often with rectangular shape, squared at ends; pits to ray parenchyma scalariform, apertures larger than intervascular pitting.

Parenchyma. Not observed.

Rays. Multiseriates to 3 cells wide (very rarely 4 cells wide); 9–57 cells, 185–945 μm. high, uniseriate margins of 1–5 rows of upright and square cells, uniseriates rare, 3–10 cells, 85–290 μm. high, composed of square and upright cells; enlarged cells present in the uniseriate margins of the multiseriate rays; 5–9 per mm.

Imperforate tracheary elements. Nature not determinable, no pitting observed.

MATERIAL. One piece of mature secondary xylem measuring 115 × 95 × 70 mm.

HOLOTYPE. U.S.G.S. Wood Collection No. D2089-20. The species is named for Professor R. H. Wetmore, Harvard University, in recognition of his long and productive interest in plant anatomy.

LOCALITY. Gallatin Fossil Forest: U.S.G.S. Paleobot. Loc. No. D2089.

The combination of small vessels that are solitary and occasionally in radial multiples, scanty parenchyma, scalariform perforation plates, opposite and scalariform intervascular pitting, and inflated ray cells occurs in the Magnoliaceae. According to Metcalfe and Chalk (1950), enlarged oil cells in the margins of rays occur in *Talauma* and *Michelia*; additionally, Canright (1955) records their presence in *Aromadendron*, *Elmerillia*, and in the West Indian species of *Magnolia*. Record and Hess (1943) refer to oil cells as being associated with tropical members of the Magnoliaceae; species of temperate areas lack this feature.

Thin sections of the above five genera were compared with the fossil. *Michelia* differs in having a large number of radial multiples and perforation plates with less than six bars. *Aromadendron* has both simple and scalariform perforation plates. The fossil corresponds in some respects to *Elmerillia*, *Talauma*, and the West Indian species of *Magnolia* (*M. hamorii* and *M. splendens* examined). While most species of *Magnolia* have numerous, crowded vessels, predominantly in radial multiples, these West

Indian species do not. Neither *Elmerillia* nor *Magnolia* has as many bars per scalariform perforation plate as does the fossil. This may not be significant, in that fossil woods might be expected to have perforation plates with a larger number of bars (a more primitive feature) than do the modern taxa to which they are related.

It was not possible to determine definitely whether terminal parenchyma was present in this Yellowstone material. No parenchyma was observed with certainty in either transverse or longitudinal sections; however, as noted elsewhere (Scott & Barghoorn, 1955), it is often difficult to distinguish parenchyma in fossil wood. Some species of *Talauma* lack terminal parenchyma; it is present in *Magnolia* and *Elmerillia*. Canright (1955) characterizes *Talauma* as having apotracheal parenchyma, but it is not present in all species.

Despite the magnoliaceous characteristics of this fossil wood, it cannot be allied positively with a single modern genus in the family. Hence, it is described as the generitype of the organ genus *Magnoliaceoxylon*.

Kramer (1974b) has listed some of the fossil woods ascribed to the *Magnoliaceae*. In North America there are three reported occurrences: *Magnolioxylon panochensis* Page from the Upper Cretaceous of California (Page, 1970), *M. michelioides* Hofmann from the Oligocene of Saskatchewan, Canada, and *Talauma multiperforata* Kruse from the Eocene of Wyoming. Of these woods only *M. panochensis* appears to be assigned correctly to the Magnoliaceae. Accordingly, it is here transferred to become **Magnoliaceoxylon panochensis** (Page) Wheeler, Scott, & Barghoorn, comb. nov. (basionym: *Magnolioxylon panochensis* Page, Am. Jour. Bot. 57: 1143. 1970).

Roy and Stewart (1970) described a specimen from the Oligocene of Canada which they considered to be conspecific with the *Magnolioxylon michelioides* described by Hofmann (1952). During re-examination of the Canadian material we found only crowded alternate intervascular pitting. Since such pitting does not occur in the Magnoliaceae, the Canadian wood is excluded from this family.

The type material of *Talauma multiperforata* (No. B-3283, Paleobotanical Collections, University of Cincinnati) was re-examined during this study. Kruse (1954) described the specimen as having scalariform, occasionally opposite, intervascular pitting and predominantly scalariform perforation plates. We found that the specimen had crowded alternate pitting, the pits being hexagonal due to crowding. The apertures were sometimes coalescent; perhaps this feature was mistaken for scalariform pitting by Kruse. Also, the majority of the perforation plates are simple rather than scalariform. This specimen is distinct from the Yellowstone *Magnoliaceoxylon*, which is characterized by opposite to scalariform intervascular pitting and exclusively scalariform perforation plates. Moreover, Kruse's specimen is not a *Talauma*. It does not belong in the Magnoliaceae, as alternate intervascular pitting does not occur in the family. Possibly, this fossil wood belongs in the Lauraceae, as is suggested by the presence of inflated secretory cells in the rays. This cannot be stated

with certainty, as neither parenchyma distribution nor vessel to ray parenchyma pitting could be observed.

There are three species assigned to *Magnolioxylon* from the Tertiary of Europe: *M. parenchymatosum* has small vessels, few bars per perforation plate, parenchyma in bands, and spiral thickenings in the vessels (van der Burgh, 1973); *M. krauselii* (Greguss) van der Burgh (1973) has smaller vessels, narrower rays, and some simple perforation plates; *M. scandens* has distinct growth rings, some simple perforation plates, and as many as 33 bars in the scalariform perforation plates (Schönfeld, 1958). Material of these species should be reviewed before possible reassignment to *Magnoliaceoxylon*.

Suzuki (1976) recently described *Michelia oleifera* from the Oligocene Tsuyazaki Formation of Japan. It differs from the Yellowstone wood in having numerous vessel multiples, a high (greater than 100 per sq. mm.) vessel density, and crystalliferous parenchyma cells.

No members of the Magnoliaceae are reported from the Kisinger Lakes flora (MacGinitie, 1974). *Magnolia* is among the genera in a preliminary list of late early Eocene megafossils from the Wind River Basin, Wyoming (MacGinitie, 1969). Magnoliaceous seeds from the late Paleocene of the Wind River Basin have been identified by Scott.

There are many temperate species in the Magnoliaceae, although others extend into the subtropics and tropics: *Elmerillia* contains seven species found in the Philippines and New Guinea; *Talauma* has 50 species now distributed in the eastern Himalayas, Southeast Asia, Malaysia, and from Mexico to tropical America (Willis, 1973).

PLATANACEAE [1]

Plataninium haydenii Felix, emend. Wheeler, Scott, & Barghoorn
FIGURES 21, 22.

Plataninium Haydeni Felix, Zeitschr. Geol. Gesell. **48**: 251. 1896.
Plataninium knowltoni Platen, Naturf. Gesell. Leipzig Sitzungsber. **34**: 130, 131. 1908.
Platanus haydeni (Felix) Beyer, Am. Midl. Nat. **51**: 564. 1954.

Growth rings. Present, narrow, marked by 2–3 rows of flattened fibers.

Vessel elements. Diffuse porous; predominantly solitary, in pairs, and with a tendency to formation of tangential arcs. Tangential diameter 41–

[1] After this paper had gone to press, a monograph by H. Süss and W. R. Müller-Stoll (Untersuchungen über fossile Platanenhölzer. Beiträge zu einer Monographie der Gattung *Platanoxylon* Andreánszky. Feddes Repert. **88**: 1–62. 1977) was received by E. W.

Süss and Müller-Stoll recognize four species of sycamore-like woods from Yellowstone: *Platanoxylon haydenii* (Felix) Süss & Müller-Stoll, *P. catenatum* Süss & Müller-Stoll, *P. knowltonii* (Platen) Süss & Müller-Stoll, and *P. platenii* Süss & Müller-Stoll.

92 μm. (mean 74 μm.); 44–108 per square mm.; length 460–900 μm.; perforation plates scalariform with 3–28 bars, most commonly with less than 10 bars; intervascular pitting opposite and subopposite, occasionally scalariform at tips; pits to parenchyma frequently elongate horizontally, scalariform.

Parenchyma. Apotracheal diffuse, as isolated cells and as short uniseriate bands.

Rays. To 22 cells wide and approximately 6 mm. high; uniseriates rare; wider rays either homocellular or heterocellular with 2–3 marginal rows of square and upright cells, narrower rays more commonly heterocellular.

Imperforate tracheary elements. Circular bordered pits mostly on the radial walls of the fibers.

MATERIAL. Seven specimens of mature, secondary xylem, D2054B-33, figured.

LOCALITIES. Gallatin Fossil Forest: U.S.G.S. Paleobot. Loc. No. D2089. Specimen Ridge: U.S.G.S. Paleobot. Loc. No. D2054B.

Of the seven specimens assigned to this taxon, four are from the Gallatin forest and three are from Specimen Ridge. They are representatives of a group of woods, common in the Eocene of western United States, that closely resemble modern *Platanus* (sycamore) woods but cannot reliably be assigned to this genus. The valid generic name for fossil woods of this structural type is *Plataninium* Unger, which has been emended recently by Page (1968) and by Brett (1972). Both Page and Brett emphasize the predominance of scalariform perforation plates in their generic concepts, and Brett, as did Vater (1884) in an earlier emendation, lists rarity of uniseriate rays as a diagnostic feature. This last feature is an important one in distinguishing sycamore woods from others with similar structure.

Page (1968) considered *Plataninium* to include fossil woods with the general structure found in *Platanus* (Platanaceae), *Fagus* (Fagaceae), *Euptelea* (Eupteleaceae), and *Citronella* and *Ottoschulzia* (Icacinaceae). All of these genera are characterized by numerous uniseriate rays together with the broad multiseriate rays. There are other distinctions between *Platanus* and these genera: *Euptelea* has perforation plates with many (up to 90) bars; *Citronella* and *Ottoschulzia* have markedly heterocellular rays and very long vessel elements (Page, 1968). Süss (1971) found height of procumbent ray cells to be another feature useful in distinguishing sycamore from structurally similar woods. The mean procumbent ray cell height in sycamore is 23–27 μm.; the ray cell height of the Gallatin and Specimen Ridge woods assigned to *Plataninium haydenii* falls within the range for *Platanus*.

In 1896 Felix described a sycamore-like wood from Yellowstone National Park as *Plataninium haydenii.* His diagnosis included these characters: distinct growth rings absent; rays noded at growth ring boundaries; vessels

extremely numerous, solitary and in pairs and irregular groups, diameter commonly 75–90 μm.; parenchyma in tangential bands, bands irregular and broken; rays 18–20 cells wide, some 1–2 cells wide; scalariform perforation plates and opposite intervascular pitting.

Later, Platen (1908) described an additional specimen of *Plataninium haydenii* and a new species, *P. knowltonii*, from Amethyst Mountain. The characters ascribed to *P. haydenii* are: distinct growth rings present; diffuse porous; vessels solitary and in tangential groups; vessel diameter generally 75 μm.; rays to 16 cells wide and to 5 mm. high. *Plataninium knowltonii* is diagnosed as having distinct growth rings, numerous vessels arranged in tangential rows, diameter of vessels up to 100 μm., intervascular pitting 5 μm. across, rays to 20 cells wide with uniseriate margins, and parenchyma in tangential bands. There do not appear to be significant differences between the diagnoses of *P. haydenii* and *P. knowltonii*, which we regard as a later synonym.

The likelihood that the Yellowstone sycamore-like woods represent a single taxon is borne out by the overlap in many features among the seven specimens of *Plataninium* that we have examined. A few examples do not show growth rings distinctly, but *P. haydenii* was described originally as lacking distinct growth rings. Among these specimens, the maximum number of bars per perforation plate varies from 10 to 41; the maximum vessel element length from 480 to 920 μm.; the maximum ray width from 16 to 26 cells. Uniseriate rays are rare. There is also variation in tangential diameter of vessels, vessel density, and abundance of parenchyma, but study of present-day sycamores indicates that such variations cannot be used to distinguish species. Süss and Müller-Stoll (1975) compared wood samples of five species of *Platanus* and concluded that size, density, and shape of the pores are not critical diagnostic features.

If these Yellowstone specimens of *Plataninium* were of different ages and were from diverse localities, they might be considered by some workers to represent distinct entities. However, they are of similar age and are in geographic proximity, and some of the specimens are intermediate in structure between the extremes listed above. We regard the specimens as exhibiting a reasonable range of variation for the single species, *P. haydenii*, as emended.

The major difference between *Plataninium* and extant sycamore wood seems to be the presence of exclusively or predominantly scalariform perforation plates in the fossil genus. This feature is mentioned in the original diagnosis of *P. haydenii*. However, Beyer (1954), who studied eight sycamore-like woods from Specimen Ridge, made the new combination *Platanus haydeni*. He describes these woods as having rays 3–10 cells wide and simple perforation plates. Nevertheless, he states (p. 565) that these specimens "conform so closely to *Plataninium haydeni* Felix that the deviations are only minute and fall well within a reasonable variation for the species." The differences in perforation plate type and ray width between Beyer's description and the original diagnosis of the species are not discussed.

The eight specimens cited by Beyer have been re-examined by courtesy of Dr. R. A. Davis, Department of Geology, University of Cincinnati. One specimen with relatively narrow rays (B-765), and another (B-779) that had wider rays more typical of Beyer's material, were sectioned. The rays had a maximum width of 16 cells in B-765 and 22 cells in B-779. Both specimens have exclusively scalariform perforation plates, the number of bars ranging from 3 to 31. It is difficult to reconcile Beyer's description with the actual anatomy of these woods. Because these specimens have exclusively scalariform perforation plates, there appears to be no justification for transferring them from *Plataninium* to *Platanus*.

Numerous occurrences of *Platanus*-like woods in the fossil record have been summarized by Prakash and Barghoorn (1961) and Prakash *et al.* (1971). In the last decade most forms with exclusively or predominantly scalariform perforation plates have been assigned to *Plataninium*; those with numerous simple perforation plates have been placed in *Platanus* or *Platanoxylon*, a name first used by Andreanszky (1951) and validated by Prakash *et al.* (1971). Two species of *Plataninium* are known from the Cretaceous of California (Page, 1968): *P. platanoides* has perforation plates with 4 to 22 bars; *P. californicum* has perforations with less than 30 bars and vessel elements longer than those found in modern *Platanus*. The Oligocene *P. europeanum* from Bohemia (Prakash *et al.*, 1971) has perforations with 13 to 30 bars. These authors have described a second sycamore-like wood from the same locality as a species of *Platanoxylon*; it is distinguished by numerous, although not predominantly, simple perforations. Both Bohemian woods show distinct growth rings. Page (1968) found a higher percentage of scalariform perforation plates in modern *Platanus* woods with indistinct growth rings as compared to those with distinct growth rings.

Sycamore-like woods are known from the Eocene London Clay Formation of England. *Plataninium decipiens* Brett (1972) has 13 to 25 bars per perforation plate, with some simple perforation plates present, especially in the early wood. In the same publication, Brett assigned another wood to *Platanus* sp. It is unclear why this specimen was called *Platanus* because it has exclusively scalariform perforation plates with 8 to 16 bars.

Fossil wood that seems truly to belong to *Platanus* has been described from Miocene sediments near Vantage, Washington, as *P. americana* Prakash & Barghoorn (1961). Simple perforation plates predominate in this wood. *Platanus* wood is also present in the Upper Miocene of Hungary (Süss, 1971) and the Oligocene of Japan (Suzuki, 1976).

A wide variety of fossil leaf types from the western United States has been assigned to the genus *Platanus*. MacGinitie (1974) points out that the genus apparently was undergoing complex genetic changes during Late Cretaceous and Paleogene time. This fact doubtless contributes to the reluctance of paleobotanists, including ourselves, to assign reasonably con-

vincing Eocene fossil woods to this extant genus, despite the fact that MacGinitie did recognize two species of *Platanus* from leaves in the Kisinger Lakes flora.

DISCUSSION

Recently, angiosperm paleobotanists have been reassessing the degree of relationship between early Tertiary and modern forms (Dilcher, 1973; Wolfe, 1973). It has been demonstrated that early Tertiary plants vary in their levels of similarity to extant plants. Some fossils are assignable to extant genera, others to families; still others cannot be reliably placed in any extant taxa. Most of the information on Paleogene plants comes from the study of leaves and pollen, rather than wood.

The eight species of Eocene fossil wood described here also show a variety of relationships to modern plants. *Alnus latissima*, *Carpinus saximontana*, and *C. absarokensis* have anatomy indistinguishable from extant members of these genera. The variable *Plataninium haydenii* has relationships with modern sycamores, but differs in having exclusively scalariform perforation plates, a feature that is more primitive. *Magnoliaceoxylon wetmorei* is a member of the Magnoliaceae, but its structural features do not seem equivalent to a single modern genus. The family Lauraceae has such homogeneous wood structure that comparison of the three species of *Ulminium* with modern genera is futile except to eliminate the ring porous species of *Sassafras*.

On the basis of eight species, it is not possible to venture more than the broadest paleoecological inferences. However, the general aspect presented by these eight plants is not dissimilar to that of larger Eocene floras. There is a mixture of so-called temperate and paratropical forms, as demonstrated by both by structure and by affinities with modern taxa. Some of the woods have well-defined growth rings with marked changes in vessel diameter and arrangement within a growth ring; the species of lauraceous wood, however, lack distinct growth rings, a characteristic not associated with temperate regions. However, it is possible that these detached pieces of wood may represent root wood, and growth rings are generally less defined in roots than in stems. Like tropical members of the Magnoliaceae, *Magnoliaceoxylon wetmorei* has inflated cells in the rays. Modern species of *Carpinus* and *Alnus* are predominantly temperate in distribution, and these Yellowstone species do not structurally resemble specimens from the southern hemisphere. *Alnus* pollen in tropical Eocene assemblages is thought to be transported from higher elevations (Germeraad *et al.*, 1968). Long distance transport of the Yellowstone woods is unlikely; it is thus possible that these Eocene species of *Alnus* and *Carpinus* may have had different ecological requirements than are now characteristic of the genera.

The early middle Eocene Kisinger Lakes flora from the nearby Wind River Basin is inferred to have grown under tropical or near tropical conditions with a pronounced winter dry season, and to have had a "distinct tropical American aspect" (MacGinitie, 1974, p. 1). This flora is con-

sidered to be distinct from older, early Eocene floras, whose primary relationships are with evergreen sclerophyllous broad-leaved and mixed mesophytic forest types, and which do not reflect the drier winter seasons of the middle Eocene. Although all of the fossil woods that can be assigned to extant taxa have New World relatives, they also represent plants which are present in either the evergreen sclerophyllous broad-leaved or the mixed mesophytic forest types. Thus far, the genus *Alnus* and the families Platanaceae and Lauraceae are common to the Kisinger Lakes flora and the Yellowstone fossil forest flora.

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EXPLANATION OF PLATES

PLATE I

FIGURES 1–3. *Alnus latissima*, sp. nov.: 1, transverse section, × 80; 2, perforation plate and opposite intervascular pitting, × 220; 3, tangential section showing aggregate ray, × 80. FIGURES 4, 5. *Carpinus saximontana*, sp. nov.: 4, transverse section, × 40; 5, tangential section showing aggregate ray, × 80. FIGURE 6. *Carpinus absarokensis*, sp. nov.: transverse section, × 70.

PLATE II

FIGURE 7. *Carpinus absarokensis*, sp. nov.: tangential section showing aggregate rays, × 80. FIGURES 8–11. *Ulminium porosum*, sp. nov.: 8, tangential section (note inflated ray cells), × 85; 9, transverse section, × 30; 10, intervascular pitting, × 250; 11, vessel to ray pitting, × 220. FIGURE 12. *Ulminium parenchymatosum*, sp. nov.: transverse section, × 45.

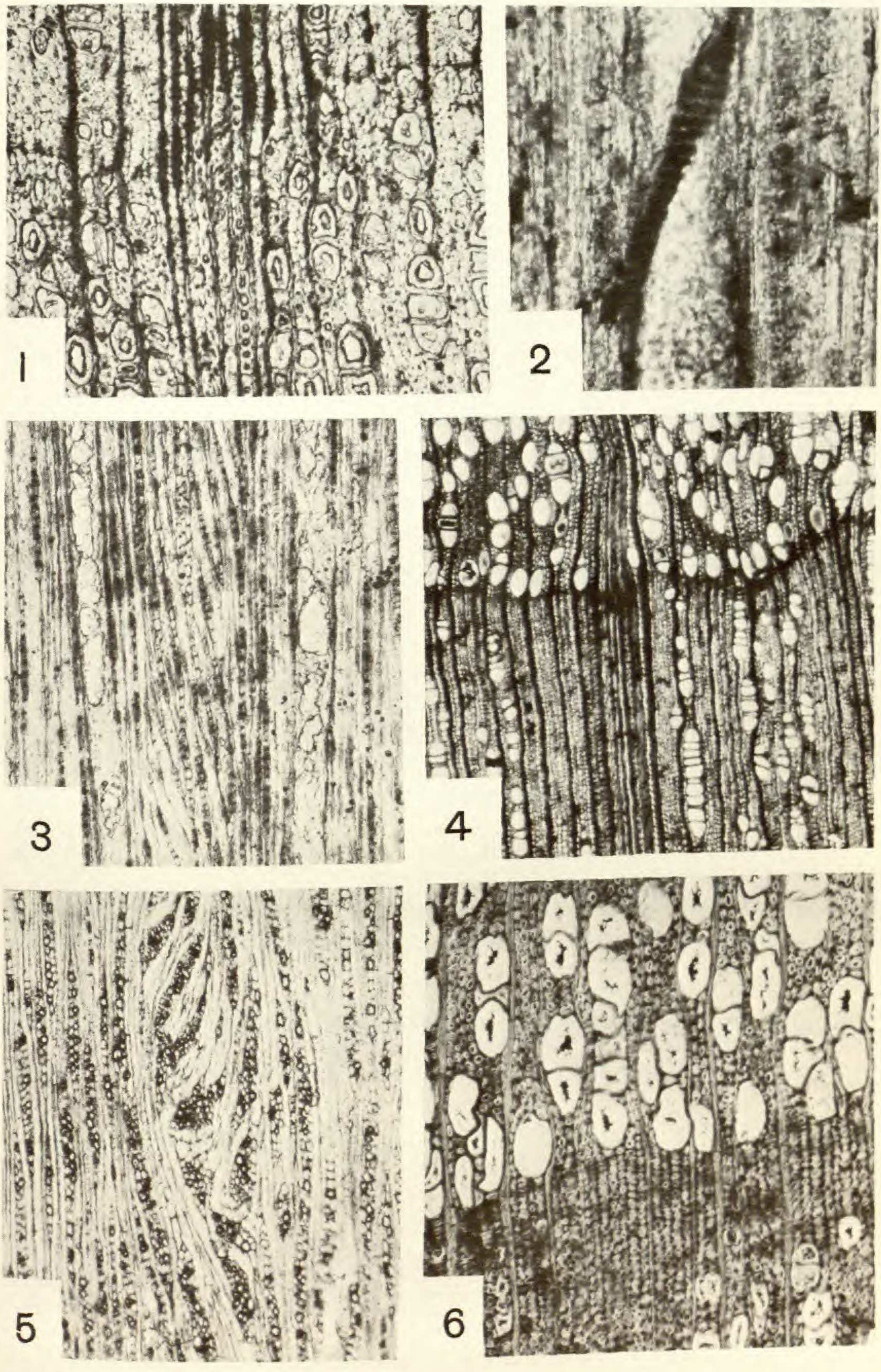
PLATE III

FIGURES 13, 14. *Ulminium parenchymatosum*, sp. nov.: 13, tangential section, intervascular pitting at left, idioblast at right, × 90; 14, vessel to ray pitting, × 200. FIGURES 15–17. *Ulminium eocenicum*, sp. nov.: 15, transverse section, × 55; 16, tangential section, idioblast at right, × 120; 17, intervascular pitting, × 200. FIGURE 18. *Magnoliaceoxylon wetmorei*, gen. et sp. nov.: transverse section, × 50.

PLATE IV

FIGURES 19, 20. *Magnoliaceoxylon wetmorei*, gen. et sp. nov.: 19, perforation plates and intervascular pitting, × 250; 20, tangential section, inflated ray cell at upper right, × 80. FIGURES 21, 22. *Plataninium haydenii* Felix emend.: 21, transverse section, × 65; 22, tangential section showing intervascular pitting and perforation plate, × 120.

Plate I



Wheeler et al., Fossil Woods

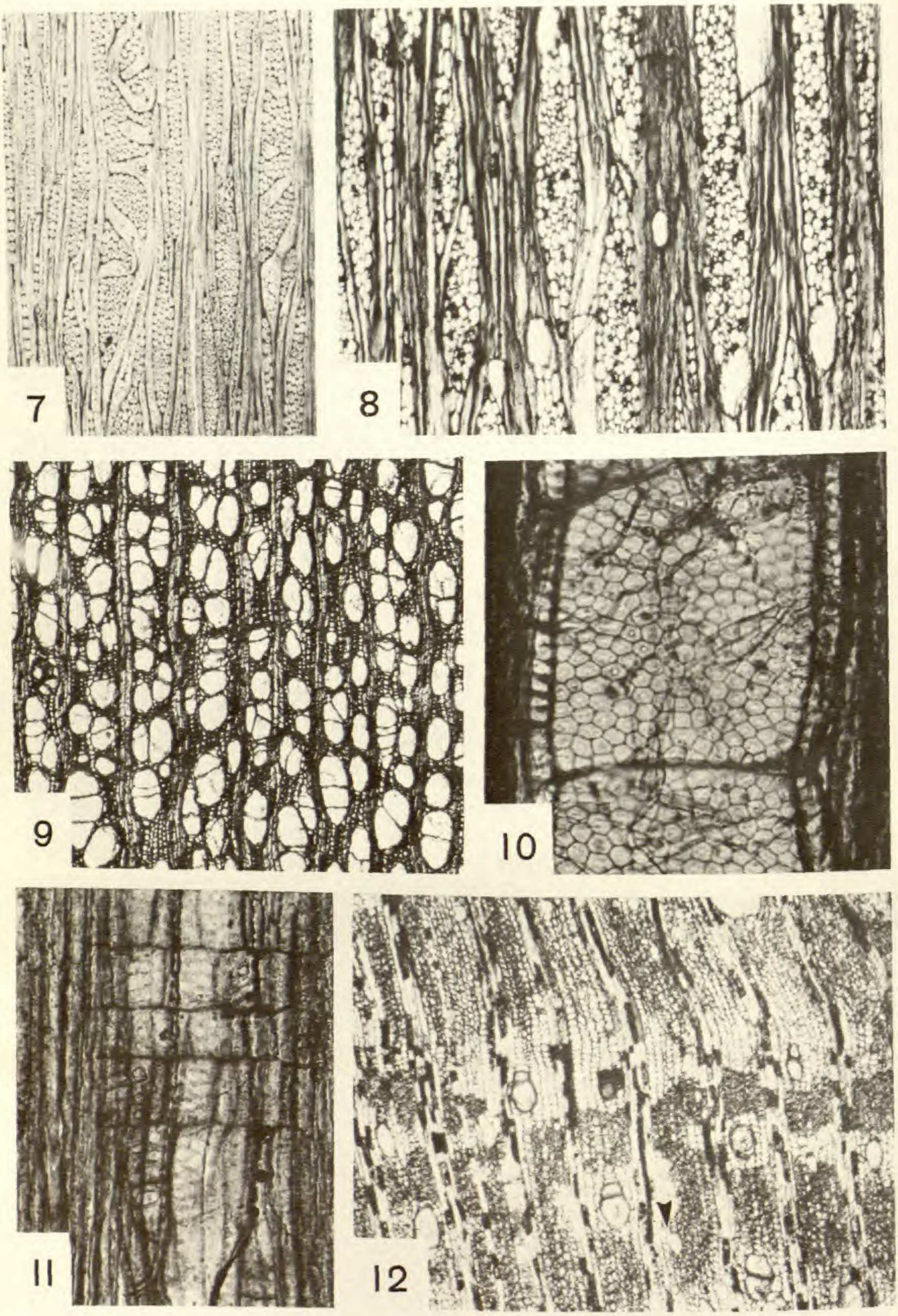


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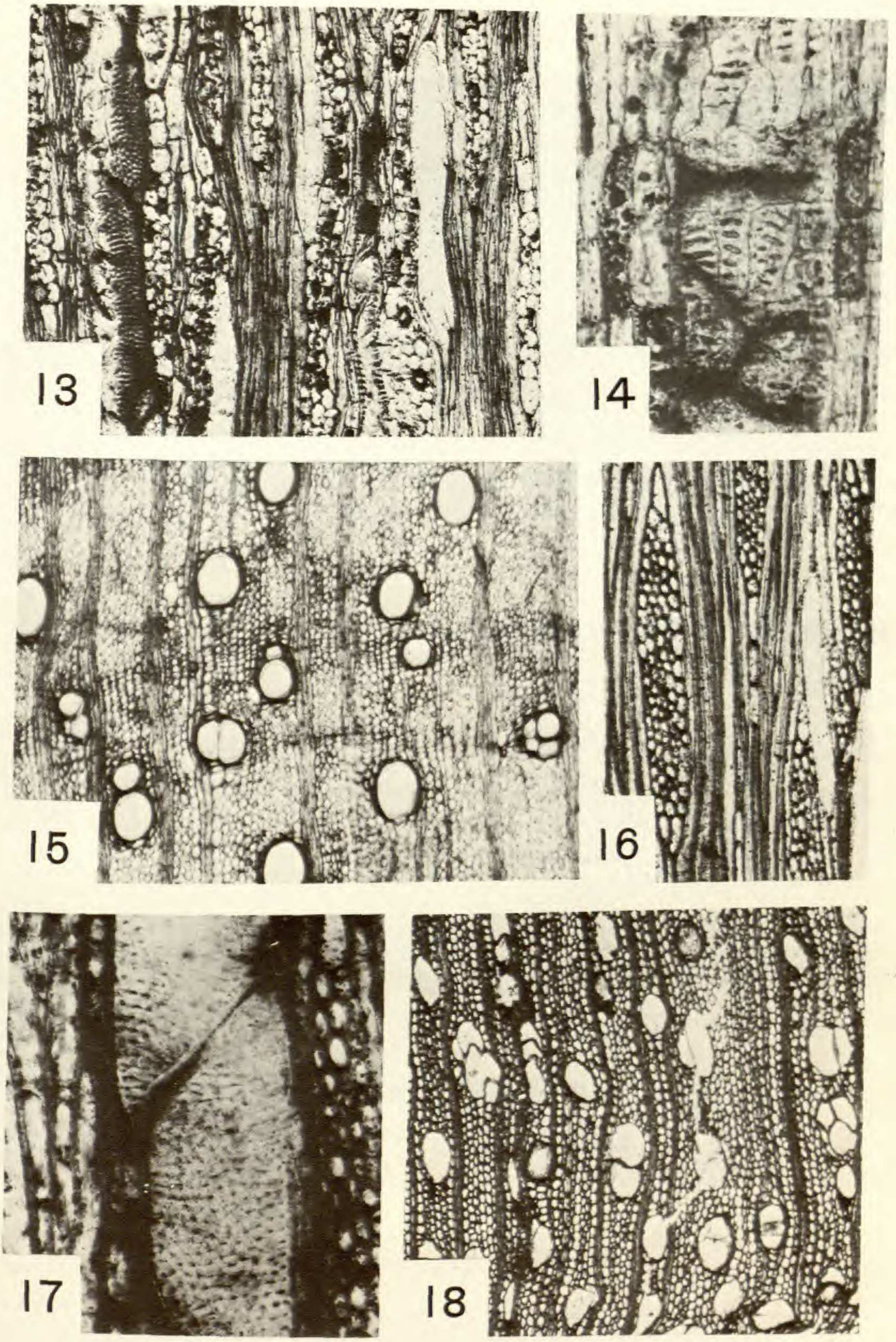
PLATE III



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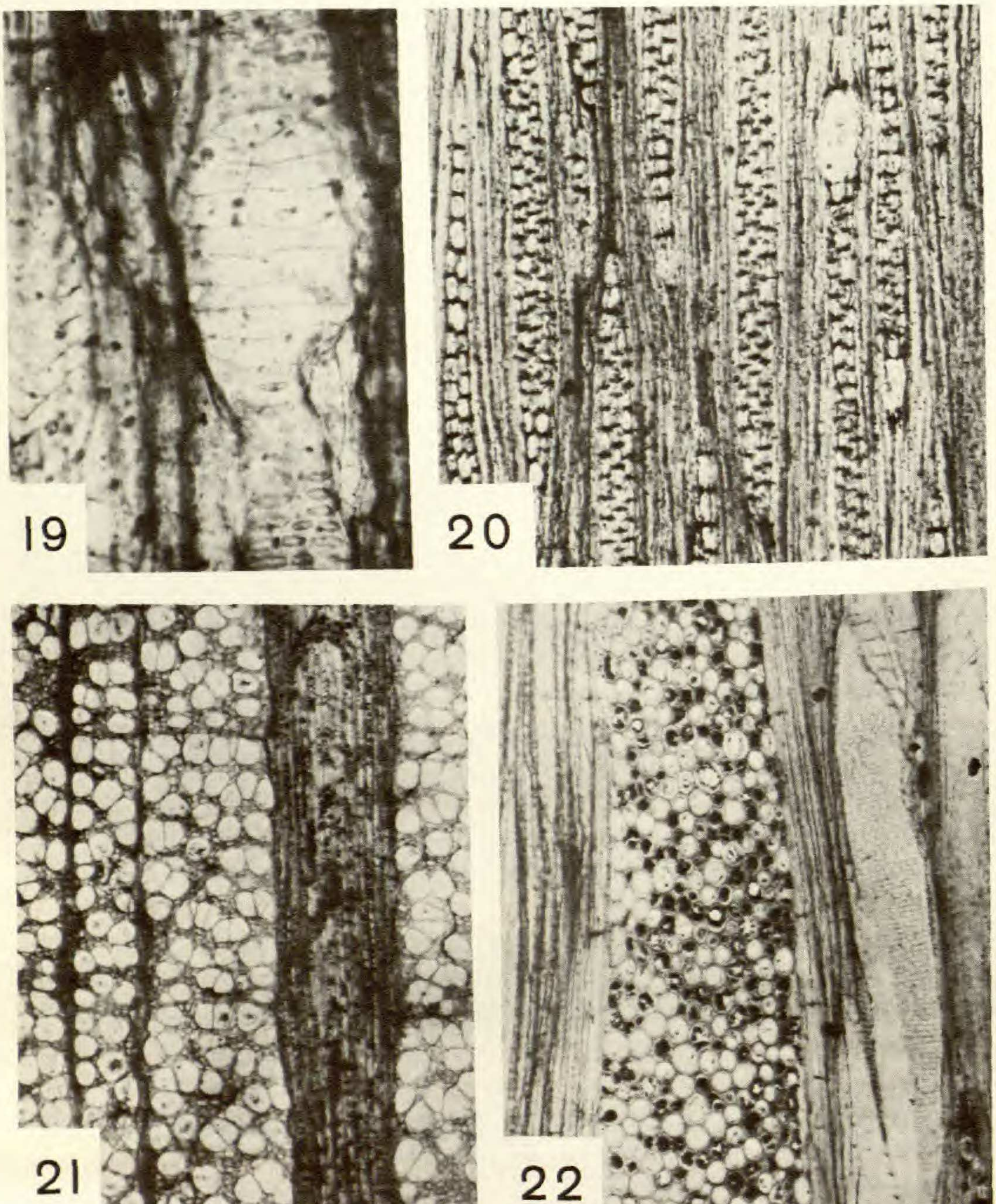

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